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Controlled Fragmentation, XXXI.

The development of rubber liners for the
grooved-charge method of controlling fragmentation

W. C. F. Shepherd and J. W. Gibson
Safety in Mines Research Establishment, Buxton



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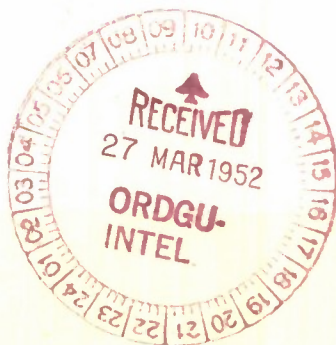
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Controlled Fragmentation, XXXI. The development of rubber liners for the grooved-charge method of controlling fragmentation

by

W.C.F. Shepherd, B.Sc., Ph.D. and J.W. Gibson, B.Sc.

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Approved

..... W.C.F. Shepherd for Director, S.M.R.E.

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Buxton Report E. 194

September, 1951

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SUMMARY

Earlier work on the development and application of the grooved-charge method of obtaining controlled fragmentation has been confined to casings with cylindrical cavities into which pre-cast charges, or fluted liners, can be easily inserted. Difficulty is experienced when the cavity is not cylindrical and when it is bulbous with a narrow neck, for it is then necessary to have a flexible liner which, shaped to the cavity, can be collapsed during insertion and is elastic enough to recover its shape.

A method of fabricating fluted rubber liners which meet this requirement has been developed. A metal former carrying the chosen fluted pattern and shaped to the cavity of the casing is sprayed with rubber latex under specified conditions. The liner, in the form of a bag, is peeled off the former and inserted into the casing. The process of filling with molten explosive helps in achieving a good fit of the liner to the cavity.

Fragmentation results with cylindrical and barrel-shaped casings are described.

INTRODUCTION

In the application of the grooved-charge method of controlling the fragmentation of a casing, there are manufacturing problems associated with the production of a charge of the required shape with the required pattern of grooves. These were overcome to a large extent in the research and development of the method by the use of a parallel-walled canister of uniform thickness, into which was inserted either a hand-made fluted paper liner (prior to filling), or a composite H.E. charge made up of pre-cast sections, each with its pattern of grooves.

Problems of manufacture were considered during the war for the 3-in. U.P. shell, the fragmenting head of which comprised a parallel tube 12.4 in. long, 0.28 in. wall thickness. The pre-casting of grooved "cheeses" to make up composite charges was not practicable for large-scale factory filling, and attention was given to methods of making "fluted liners", either of paper or of thin metal, which could be placed in the shell before filling and left in the filled shell. Details of the development of suitable methods are given by Shepherd (Ref.1); the most efficient liner was produced by a pulp-moulding process which resulted in a sheet of paper of the required size in which the pattern of flutes was moulded. Recent developments in the field of plastics suggests that there may be materials more suitable than paper in giving sharpness of profile to the grooves. Such a process, however, assumes that the inner surface of the casing, not necessarily cylindrical, is such that it can be fitted by a liner which, moulded preferably as a flat sheet, is bent round (e.g., into a cylinder) and inserted into the cavity within the casing before filling. For practical purposes, this limits the application to cavities of cylindrical or conical shape where the bore at the point of insertion is not less than the bore along the casing. Most H.E. shells, and other shaped warheads, however, have bulbous cavities and are not easily fitted by non-flexible liners.

The liner requires a certain strength and rigidity in order to retain its shape during the filling process, and (with some missiles) to withstand the forces to which it may be subjected during projection of the missile. These forces may be considerable in the case of a gun-projected shell, and investigations have been made of their effect on paper and copper foil liners fitted into 4-in. shells having a suitably-shaped cavity. (Ref.2 and 3). It was found that the liner must fit closely to the inner surface

of the shell and that the hand-made paper liner, dipped in shellac varnish and allowed to dry before use, withstood the set-back and centrifugal forces better than the copper liner. In most cases the liner, which was fitted only along the central parallel-walled zone of the shell, was set back slightly into the coned end of the cavity, causing a slight breakdown of control.

It was natural that attempts should be made to produce a shaped liner of rubber or soft plastic material which would be sufficiently flexible and collapsible to be inserted through the neck of, say, a barrel-shaped casing, and yet strong and elastic enough to recover its shape and withstand the forces to which it might be subjected. The grooves must be well defined and, apart from the liner material which should not exceed .015-.020 in. in total thickness, should be air-filled. Various ways in which this ideal might be achieved have been examined, and several forms of rubber and plastic materials have been tested. An interesting idea, that the grooves might be made of micro-porous rubber in which the rubber forms only a small proportion of the total thickness, was not found to be practicable. The latest results show that, if the grooved-charge method for controlling fragmentation is to be adopted, the use of thin, moulded rubber liners is a satisfactory way of overcoming the difficulties associated with bulbous cavities.

EXPERIMENTAL METHOD

The method consists of the manufacture of a former, suitably grooved and similar in size and shape to the charge to be cast (or to the cavity to be filled), and the development of a process whereby the former is covered by a uniform thin skin of elastic material which can be peeled off without distortion of its shape. The materials which have been tested are self-vulcanising rubber latex^{xx} and P.V.C. paste^{xxx}, both of which are fluid mixtures which form elastic solids on heating. With the limited facilities and experience at S.M.R.E., the rubber latex was the easier to handle and has been used more widely than the P.V.C. paste; it solidifies at about 45°C. in 5-8 minutes or even at room temperatures over longer periods, whereas the P.V.C. requires a heat treatment at about 150°C. It is emphasised, however, that a comprehensive search has not been made for the best material, and questions such as compatibility with the explosive have not been seriously considered. The results with rubber latex, however, are most encouraging, and there is wide industrial experience with this technique of moulding containers.

1. Manufacture of former - Formers are machined from either mild steel or copper-free aluminium alloys and three types of casing have been considered.

One of the model bombs used extensively at Buxton is 7.8 in. long, with a wall thickness of 0.125 in. and 1.25 in. in internal diameter. Described in detail in previous reports (Ref.4) it has screwed-in plugs of length 1.25 in. and 0.75-in. distance pieces, leaving an effective fragmenting length of 3.8 in. A former designed to give diamond-shaped fragments (Ref.5) was made for this bomb and is shown in Fig.1; the collection of fragments should comprise 143 pieces of mass about 0.62 oz. together with some smaller pieces. The grooves, .075 in. deep, were cut with a 60°-angled milling cutter, along lines 30° to the longitudinal in a cylindrical bar 3.8 in. long and 1.235 in. in diameter.

A barrel-shaped casing of model bomb size is shown in Fig.2; the barrelled portion is 4 in. long, with wall thickness of 0.125 in. and an internal diameter varying from 1.25 in. to 2.00 in. on a circular arc. The cylindrical ends of the casing are fitted with screwed-in plugs, 1.25 in. long. The former (Fig.2) is assembled from ten sections, each containing 20 grooves of apex angle 75° and .075 in. deep. The method of construction

^{xx}"Revultex", manufactured by Revertex Ltd., 27-29 Tavistock Place,
London, W.C.1

^{xxx}"Welvic" paste, manufactured by I.C.I. Ltd., Plastics Division

is illustrated by Fig.2; each section is cut on the gearwheel principle, by a 75° cutter, and the ten are pinned together with appropriate staggering of grooves. The diameter is made everywhere .015 in. less than the corresponding internal diameter of the casing to allow for the thickness of the rubber liner.

The third application was an attempt to mould fluted rubber liners to fit the large parallel-wall casings described in Ref.5. Of length 14 in., wall thickness 0.4 in. and internal diameter 2.9 in., these mild steel tubes are fitted with screwed-in brass end-pieces leaving a fragmenting length of 12 in. In order to produce full-length bar fragments a simple cylindrical former was constructed; it consists of a cylinder 2.88 in. in diameter, 16 in. long, along which are milled equally spaced grooves of apex angle 75° and depth 0.2 in.

2. Production of liner - There are several industrial processes for the conversion of rubber and plastic pastes into a variety of articles ranging from gloves to bed mattresses; self-vulcanising rubber latex is particularly suitable for the "dipping" process. This comparatively simple method is described in commercial pamphlets and is very effective when the former (or mould) has a smooth surface; when the mould carries sharply defined grooves, however, difficulty is experienced because the latex flows away from the sharp edges. We find that a spraying technique is much more successful in this respect. The former, heated to about 45°C., is slowly rotated and the latex is sprayed at a pressure of about 15 lb. per sq.in. from a small spray-gun outfit; the attainment of a uniform thickness is a matter of judgement and experience. After the rubber has solidified, it is dusted with French chalk and peeled-off the former. Examples of rubber liners are shown in Figs.1, 2 and 5. It is convenient to close the liner at one end, so that it can be inserted into the casing as a bag. The weight of the molten explosive helps to press the liner closely against the wall of the cavity when the high explosive filling is poured into the cavity in the usual way.

It was thought, at one time, that it might be necessary to back the liner (before removal from the former) with a thin skin of plain rubber sheeting secured with a rubberised adhesive - in this way to add to the strength of the liner and to entrap air in the grooves so that they could not collapse when the H.E. was poured into the liner. This precaution has not been found necessary, however, with the liners so far made, but it is one which should be borne in mind as a possible refinement of the method.

EXPERIMENTAL RESULTS

In the Appendix are given the fragmentation results* of five casings, two model bombs (one natural and one controlled), two barrel-shaped casings (one natural and one controlled) and one large canister which was broken into bar fragments; photographs of the collected sets are given in Figs.3, 4 and 5 and histograms in Fig.6. The threaded ends of the various casings form a considerable proportion of the weight of the casing. These portions, though often fragmented, cannot be controlled; the threaded pieces remain recognisable and they are separately sorted during the classification of the fragment collection, being shown as a total weight in the Tables. Percentage weights are based on the full weight of the casing, however, and this should be borne in mind by the reader when considering the efficiency of the control. The model bomb is controlled to give fragments of about 1.75 gram; with the barrel casing, however, the weight of fragment varies along its length and the mass distribution is consequently skew-shaped with a peak about 2 gram. The efficiency of control with the barrel-shaped casing is demonstrated by the photograph in Fig.7; in connection with another investigation into the dispersion of fragments (to be reported later, Ref.6) casings, with their axes vertical, are fragmented in a layout of upright strawboard packs and the co-ordinates of all strikes noted. The second sheets of six adjacent packs, circumferentially covering about 180° of the fragment band are shown in Fig.7 and the holes produced by the

* Fragmentation was carried out in a sawdust pit

controlled fragments have been identified. (There are additional holes owing to the strawboard sheets having been used for previous shots). There is no indication, however, of any secondary break-up of the controlled fragments and the ten rows corresponding with the ten staggered sections of the liner are easily identified.

In Fig.5 is shown the collection of rod fragments produced from the break-up of the 0.4 in. wall casing; some of these are slightly bent, but on the whole have suffered but slight distortion on impact with the sawdust and, possibly, with the brick wall behind it. Their average mass, 13.22 oz., is slightly less than the expected value of 13.95 oz., the difference being due to the loss of small fragments and dust caused by chipping and erosion.

DISCUSSION

Experiments are in progress to apply the fluted rubber liner technique to the fragmentation of gun shells into bar fragments and into smaller pieces of chosen mass. A limitation to the minimum fragment size obtainable is immediately obvious, however, where shaped warheads are concerned. The staggering of adjacent sections requires that the number of grooves in a ring be kept constant; this number has a maximum value which is a function of the wall thickness and the smallest diameter of the casing under consideration (Ref.5); consequently, when the diameter changes along the length of the casing, the fragment size will increase with the diameter. In the case of a shell, however, sacrifice in control at the end portions may be justified in order to achieve the highest number of fragments from the central zone.

No difficulties have been encountered with regard to the rubber liner retaining its shape during the filling process. In fact, as explosive is poured in, the liner tends to fit more closely to the case wall, trapping air in the grooves in the process. If the liner is required to have additional strength and rigidity there may well be treatments which, if applied to the liner after insertion and prior to filling, would produce the desired property. The wide experience available industrially on the application of rubber latex has not indeed been tapped during this investigation.

As a means of producing a grooved charge within a casing, however, the method appears to be most promising and work is being continued to further its application to service shells and warheads.

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6. H. Titman & T.L. Wall; "Dispersion of fragments"; work in progress

ACKNOWLEDGEMENT

Mr. N.L. Heathcote was largely responsible for the careful experimental work associated with the manufacture of the rubber liners and the fragmentation of the casings.

APPENDIX, Report E.194

TABLE 1 - Model bomb casings, natural and controlled fragmentation.
Specification of casings

	Natural	Control
Weight of casing, gm.	516.5	520
Weight of explosive, gm.	116.5	111
Weight of unthreaded part of casing, gm.	253.6	268.4

Sum of numbers and weights of fragments

All fragments down to, gm.	Number		Weight, gm.		Percentage weight	
	Natural	Control	Natural	Control	Natural	Control
3.1		1		3.11		0.60
2.7		2		5.91		1.14
2.4	1		2.41		0.47	
2.3		3		8.22		1.58
2.2		4		10.48		2.01
2.1		7		17.06		3.28
2.0		14		31.36		6.03
1.9	4	25	8.18	52.73	1.59	10.14
1.8	5	42	10.01	84.10	1.94	16.17
1.7	9	69	17.01	131.17	3.30	25.22
1.6	15	91	26.88	167.54	5.21	32.21
1.5	16	104	28.43	187.78	5.51	36.10
1.4	21	110	35.81	196.59	6.94	37.79
1.3	27	114	43.95	202.01	8.52	38.83
1.2	35	118	53.89	206.95	10.44	39.78
1.1	48	123	68.92	212.71	13.35	40.89
1.0	58	127	79.48	216.88	15.39	41.69
0.9	65	130	86.04	219.73	16.66	42.24
0.8	74	132	93.63	221.42	18.13	42.56
0.7	98	137	111.75	225.17	21.64	43.28
0.6	128	140	131.18	227.05	25.40	43.64
0.5	173	153	156.07	234.23	30.22	45.02
0.4	214	163	175.03	238.74	33.89	45.89
0.3	284	176	199.50	243.27	38.63	46.76
0.2	352	205	216.79	250.06	41.98	48.07
0.1	464	255	232.37	257.23	45.00	49.45
< 0.1			21.19	11.20	4.10	2.15
Thread			262.94	251.57	50.90	48.40
Total			516.50	520.00	100.00	100.00

TABLE 2 - Barrel-shaped casings, natural and controlled fragmentation.
Specification of casings

	Natural	Control
Weight of casing, gm.	584.5	563
Weight of explosive, gm.	252.5	235
Weight of unthreaded part of casing, gm.	435	423

Sum of numbers and weights of fragments

All fragments down to, gm.	Number		Weight, gm.		Percentage weight	
	Natural	Control	Natural	Control	Natural	Control
4.4	1		4.47		0.76	
4.1	2		8.57		1.46	
3.7	3		12.35		2.11	
2.6	7		23.01		3.93	
2.3	9	5	27.65	11.62	4.72	2.06
2.2	10	29	29.90	65.44	5.10	11.62
2.1		59		129.75		23.04
2.0	14	94	38.07	201.89	6.50	35.85
1.9	20	119	49.72	250.63	8.49	44.51
1.8	25	141	59.09	291.46	10.09	51.76
1.7	28	160	64.36	324.77	10.99	57.68
1.6	32	168	70.86	338.05	12.10	60.04
1.5	43	175	87.69	349.05	14.98	61.99
1.4	51	181	99.22	357.65	16.95	63.52
1.3	58	189	108.52	368.42	18.54	65.43
1.2	71	194	124.62	375.45	21.29	66.68
1.1	86	199	141.70	381.13	24.21	67.69
1.0	94		149.99		25.63	
0.9	116	200	170.61	382.10	29.16	67.86
0.8	131	203	183.37	384.70	31.34	68.32
0.7	158	204	203.90	385.43	34.85	68.45
0.6	199	208	230.74	388.00	39.44	68.91
0.5	259	210	263.71	389.02	45.08	69.09
0.4	344	223	302.21	394.76	51.67	70.11
0.3	447	231	338.36	397.48	57.86	70.59
0.2	606	243	378.64	400.57	64.75	71.14
0.1	857	281	416.24	405.65	71.18	72.04
< 0.1			18.84	17.28	3.22	3.07
Thread			149.42	140.07	25.60	24.89
Total			584.50	563.00	100.00	100.00

TABLE 3 - 0.4-in. wall canister, bar fragment control
Specification of casing

	lb. oz. dr.
Weight of casing	16 3 8
Weight of explosive	3 0 7
Weight of unthreaded part of casing	13 15 3

Number and weight of fragments in each class

Class oz.	Number	Weight lb. oz. dr.	Percentage weight
12 - 14	16	12 14 10	79.63
1/2 - 1	2	1 6	0.53
1/4 - 1/2	8	2 14	1.10
1/8 - 1/4	18	3 2	1.21
1/25 - 1/8	95	6 13	2.62
1/50 - 1/25	108	3 0	1.15
1/100 - 1/50	166	2 7	0.94
< 1/100		2 15	1.14
Thread		1 14 5	11.68
Total		16 3 8	100.00

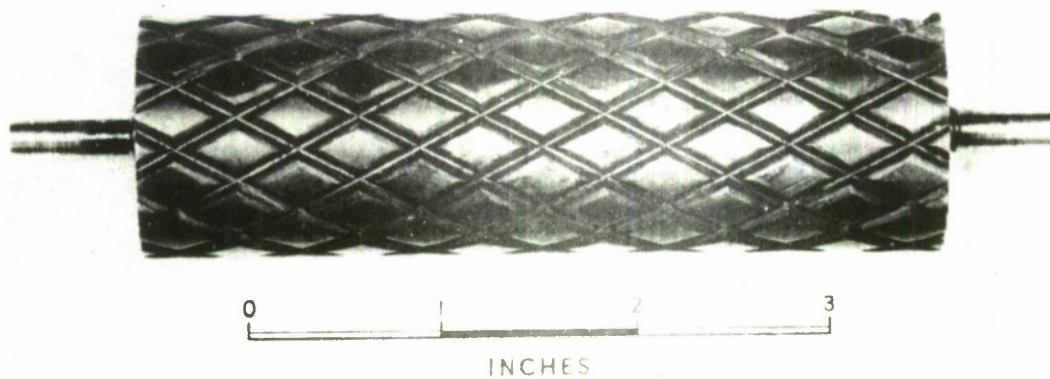
Sum of numbers and weights of fragments

All fragments down to, oz.	Number	Weight lb. oz. dr.	Percentage weight
12	16	12 14 10	79.63
1/2	18	13 0 0	80.16
1/4	26	13 2 14	81.26
1/8	44	13 6 0	82.47
1/25	139	13 12 13	85.09
1/50	247	13 15 13	86.24
1/100	413	14 2 4	87.18

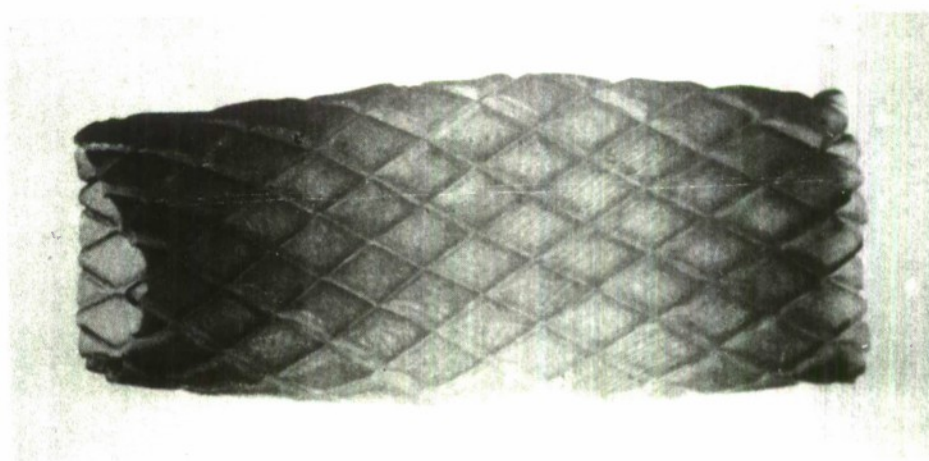
Weights of controlled bar fragments, oz.

13.47	13.51	13.37	13.23	13.23	12.98	12.94	12.84
12.84	12.84	12.80	12.70	12.66	12.45	12.42	12.34

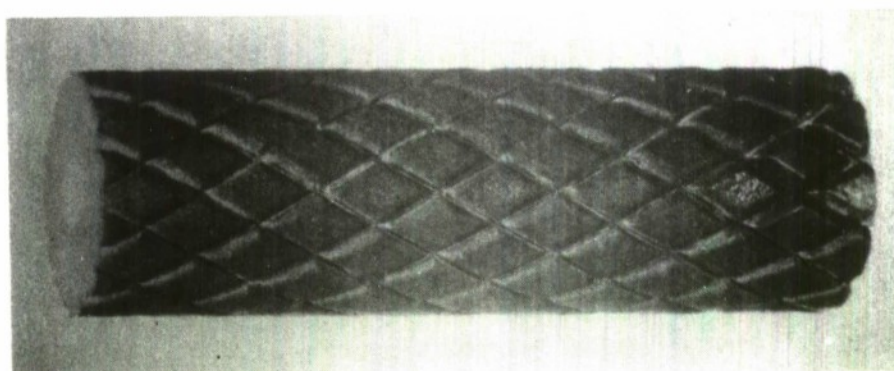
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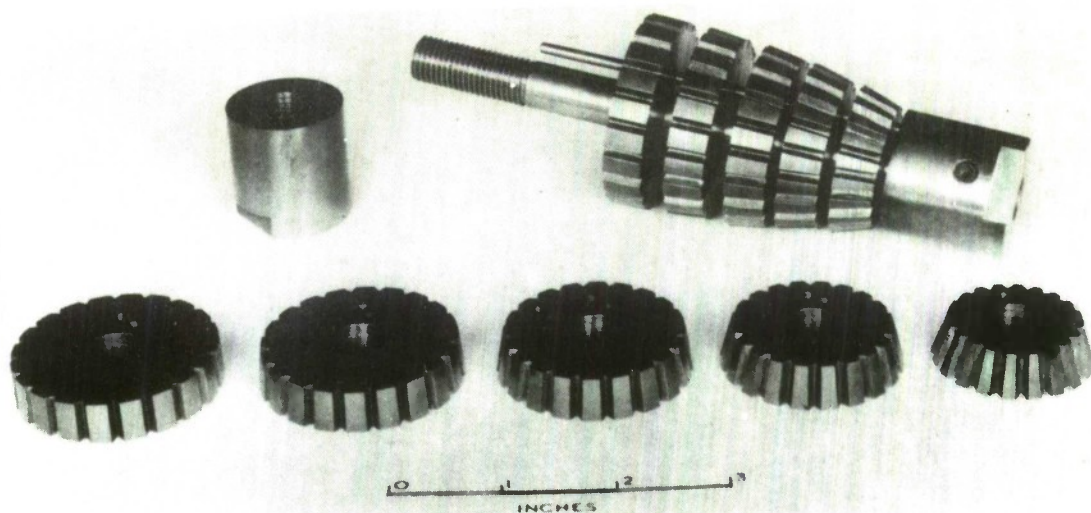


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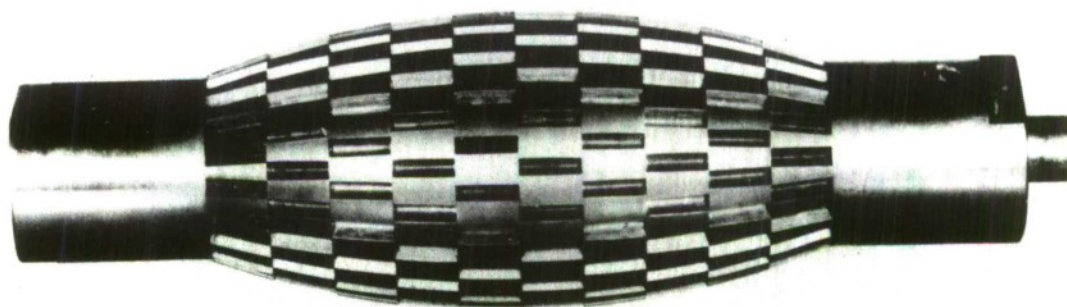
MODEL-BOMB CASING

FIG. 1

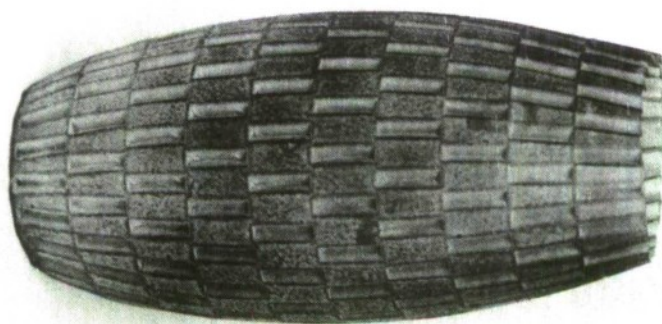
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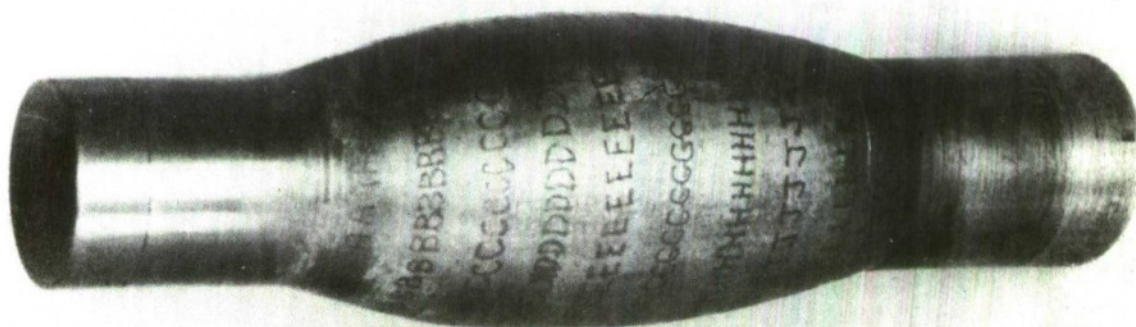
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RUBBER LINER



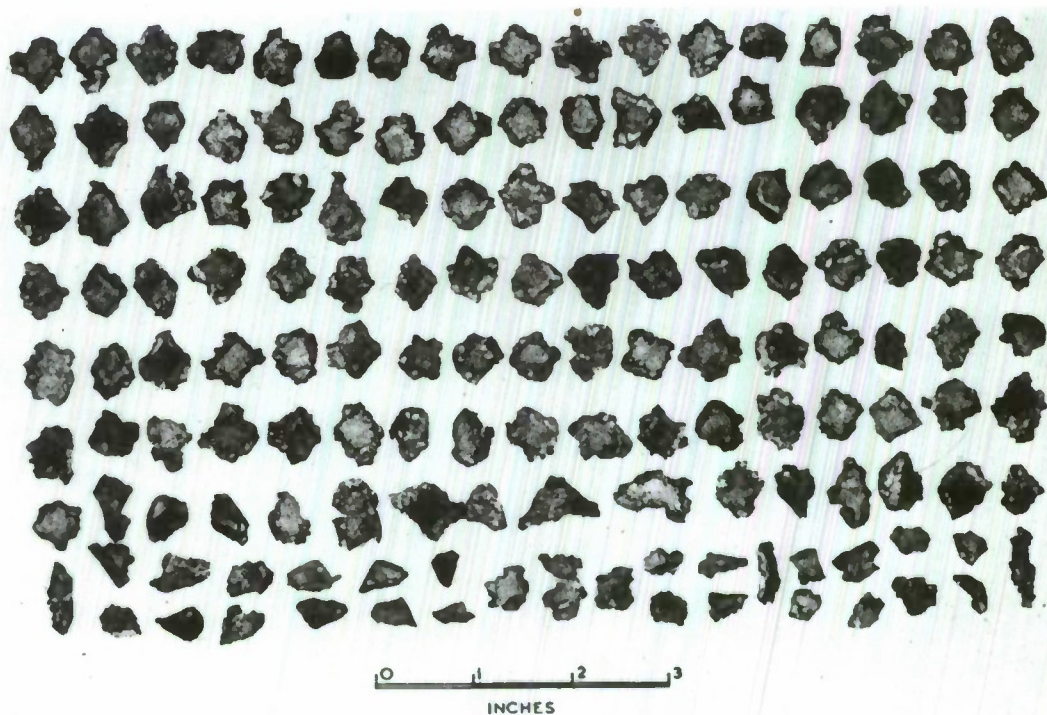
BARREL-SHAPED CASING

FIG. 2



NATURAL FRAGMENTATION

All fragments of mass greater than 0.5 grams representing
61 per cent of the unthreaded part of casing



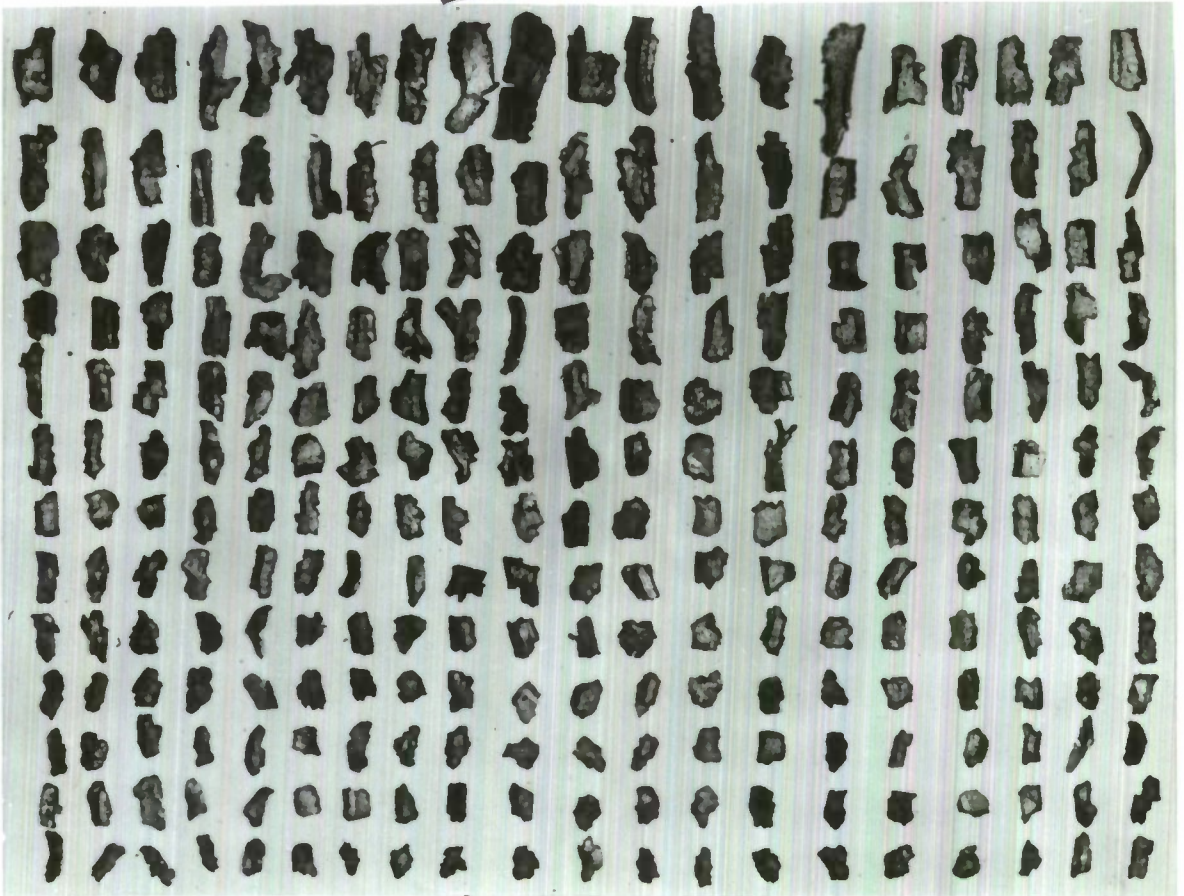
CONTROLLED FRAGMENTATION

All fragments of mass greater than 0.5 grams representing
87 per cent of the unthreaded part of casing

MODEL-BOMB FRAGMENTS

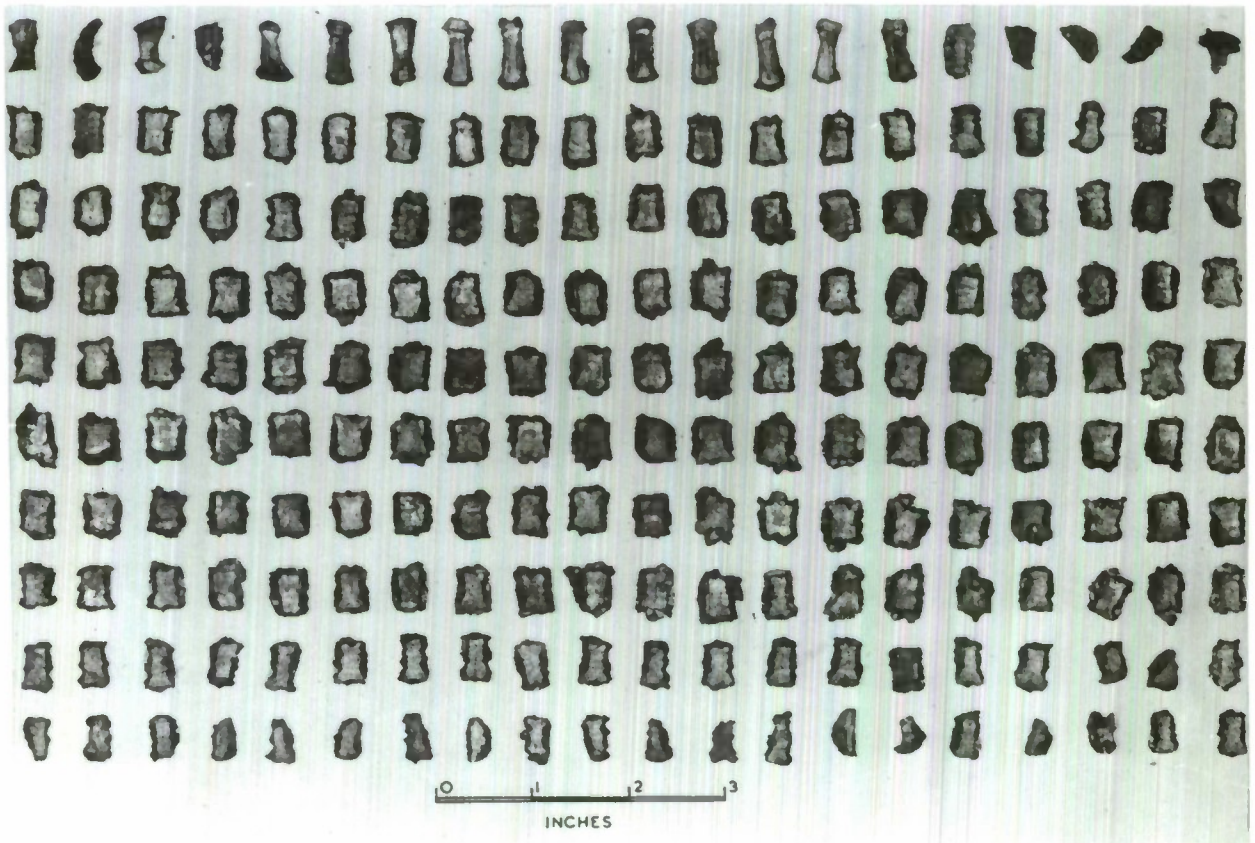
FIG. 3

~~CONFIDENTIAL~~



NATURAL FRAGMENTATION

All fragments of mass greater than 0.5 grams representing
61 per cent of the unthreaded part of casing



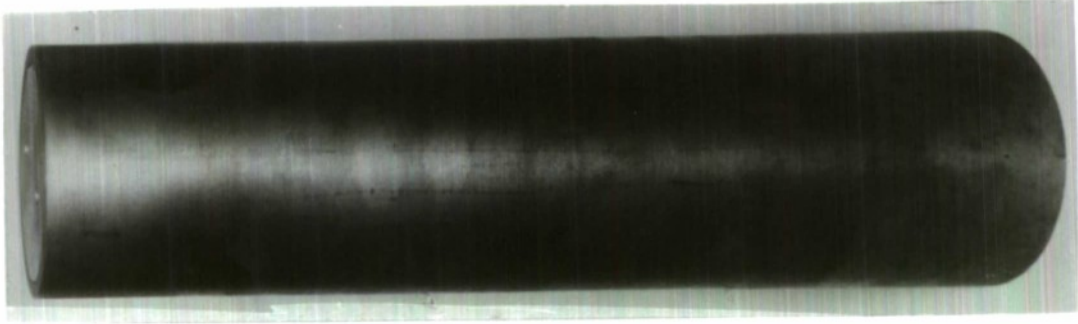
CONTROLLED FRAGMENTATION

All fragments of mass greater than 0.5 grams representing
93 per cent of the unthreaded part of casing

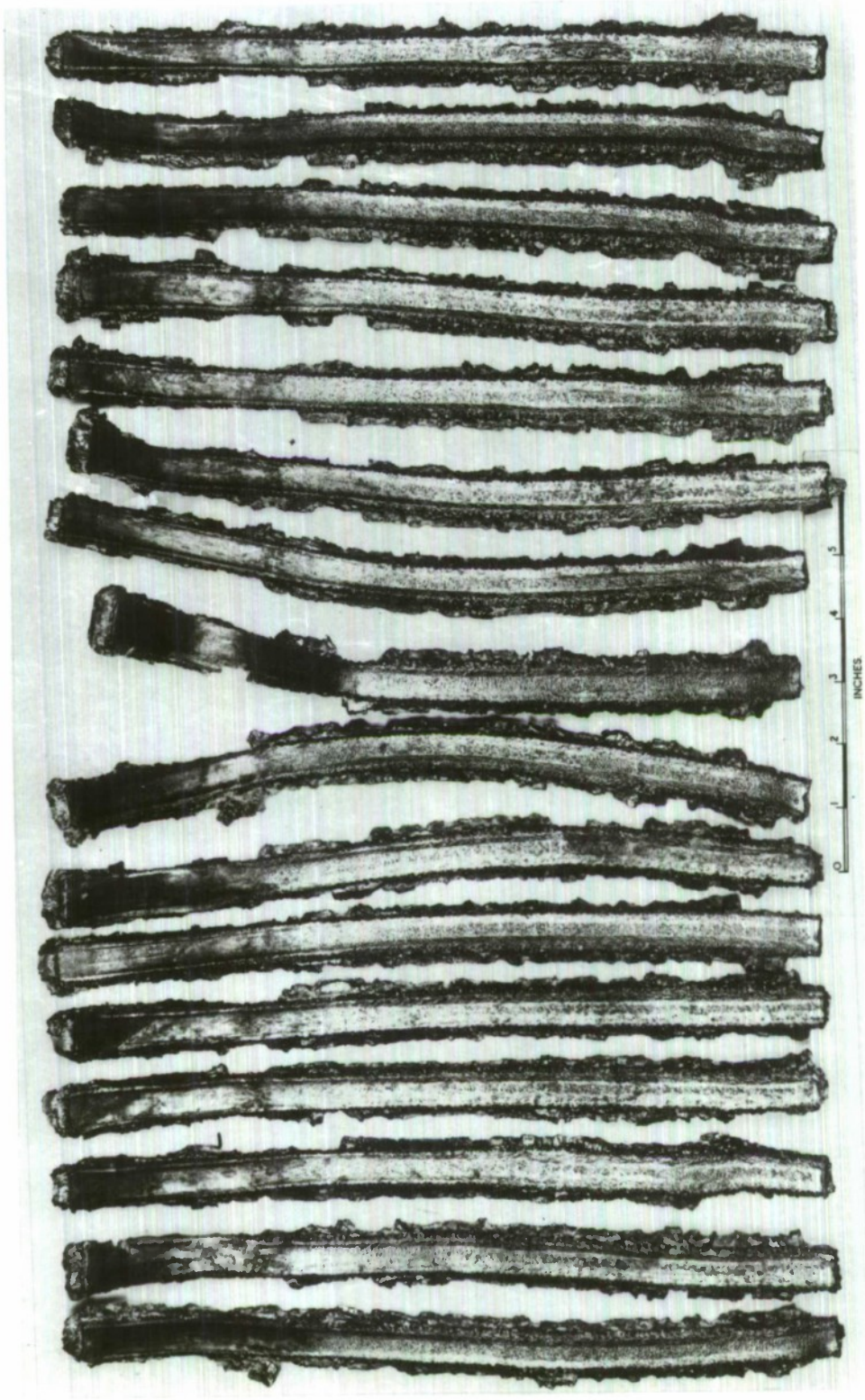
BARREL-SHAPED CASING FRAGMENTS

FIG. 4

CONFIDENTIAL

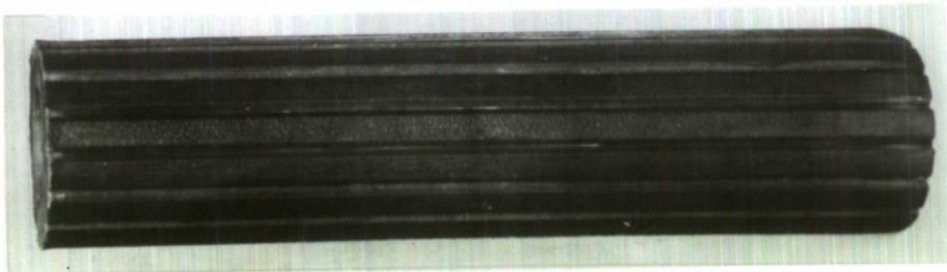


CASING



BAR FRAGMENTS FROM 0.4" WALL CASING

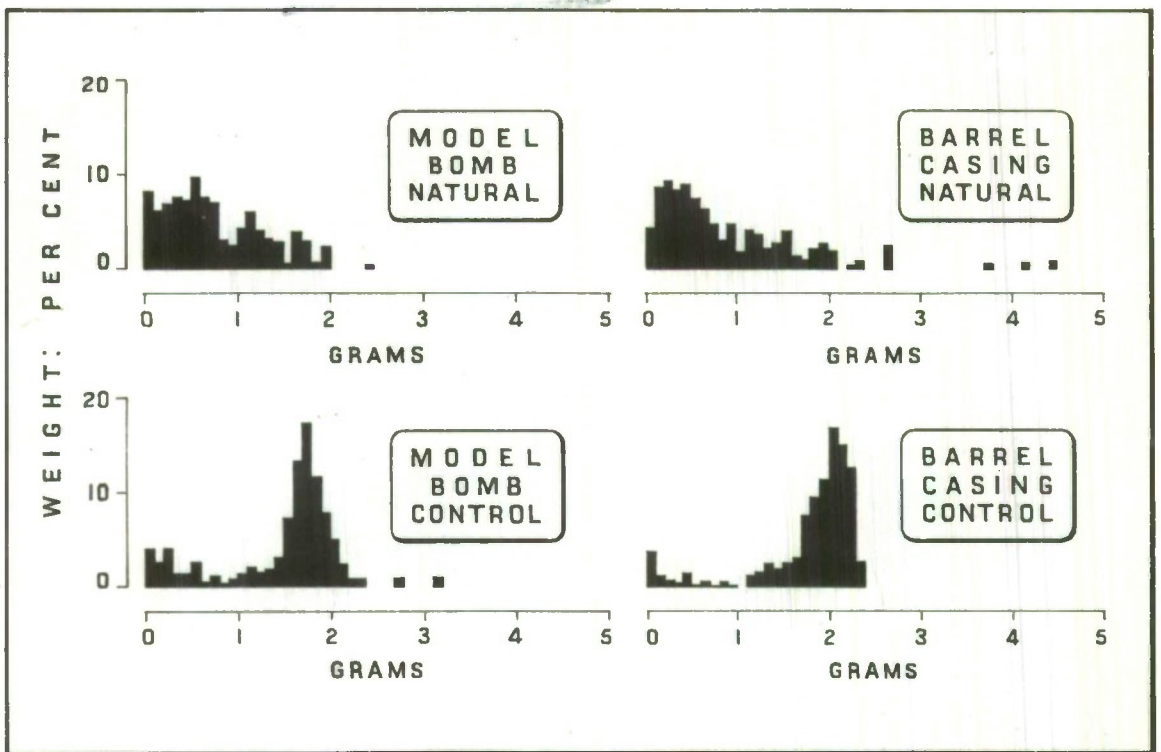
Representing 90 per cent of the unthreaded part of casing



FILLED
CHARGE

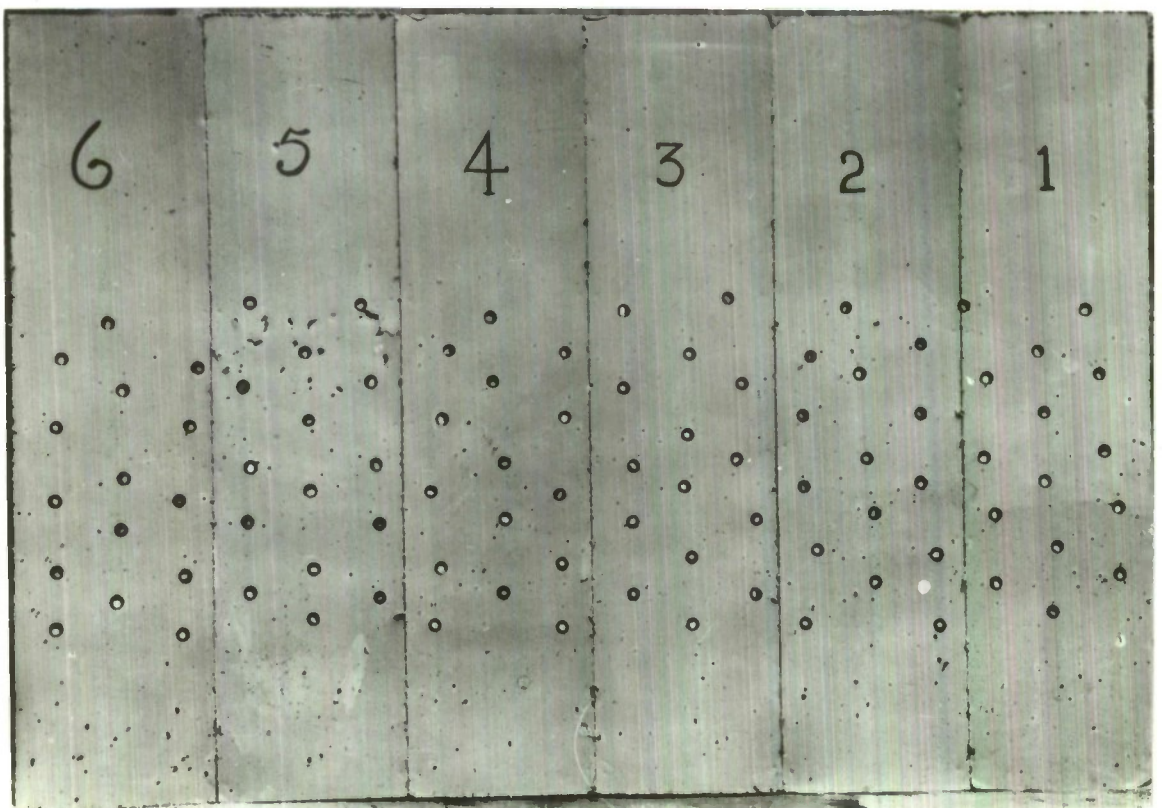
FIG. 5

~~CONFIDENTIAL~~



WEIGHT-MASS HISTOGRAMS

FIG. 6



TARGET SHEETS SHOWING DISPERSION OF FRAGMENTS
FROM CONTROLLED BARREL-SHAPED CASING

FIG. 7



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Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#:

Date of Search: 16 February 2007

Record Summary:

Title: Controlled fragmentation XXXI: development of rubber liners for
grooved-charge method of controlling fragmentation
Covering dates 1952
Availability Open Document, Open Description, Normal Closure before FOI
Act: 30 years
Former reference (Department) Report No 18/51
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

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